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(9) 30 June 1959

(8) See p. 12
(10) 18 p. incl. illus, tables.
(13) N.A

Commander
Air Force Cambridge Research Center
Laurence G. Hanscom Field
Bedford, Massachusetts

Attention: John N. Howard, CRZCI
Geophysics Research Directorate

Subject: (12) Contract No. AF 19(604)-5877
(6) "Research on Atmospheric Attenuation of Infrared Radiation"
(11) ~~Progress~~ Report No. CML-L-E173-1
(7) Progress rept. no. 1

Dear Sir:

This is the first progress report of the work done under the subject contract. The effort began during mid-May of this year. The scope and purpose of the contract were extensively discussed with personnel from Cambridge Research Center, Patrick and Lowry Air Force Bases. Thus it was possible to expedite detailed planning and attempt accomplishment of the many facets that required polishing before the onset of the Intraservice Radiation Measurement Program of 1959-1960 (IRMP 59/60).

The objectives of this ~~particular~~ contract are centered about infrared transmission and include:

(1) An investigation of the slant path attenuation between sea level and the tropopause;

(2) Calculation of attenuation coefficients to correct particular IRMP data;

(3) Correlation of attenuation data with meteorological conditions;

(4) Possible separation of absorption and scattering mechanisms; and

G. C.

cont'd on p. 2

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(5) Comparison of scatter data to theory.

In order to carry out the program measurement phase, it is planned to use a number of blackbody sources carried aloft by means of balloons. It is necessary to know: (1) the radiance or radiant intensity of the source as a function of time; (2) the absolute value of irradiance and its distribution at the ground-based measuring instrument as a function of time; (3) the position of the balloon relative to the ground station as a function of time; and (4) the meteorological conditions at the balloon location as a function of time.

The work during the past month ~~has been~~ was concerned with the following problems:

(1) Choice of ground-based measuring equipment;

(2) Choice of operating procedures to insure tracking of the source sufficiently well to eliminate errors caused by only partial inclusion of source image within the spectrometer slit;

(3) Studies of methods to monitor source radiance with expendable balloon-borne equipment;

(4) Error analysis to determine allowable magnitudes of measurement errors; and

(5) Collection and organization of recording equipment to produce suitable data for subsequent analysis.

One of the severe problems in this program is that of keeping the entire image of the source within the jaws of the entrance slit. The work reported describes the optical implementation necessary at the spectrometer to optimize its measuring capability.

Since the irradiance expected at the ground station from the airborne emitter will be very small, some form of collecting optics is required to provide the necessary optical gain. It is expected that the image of the emitter produced by the collecting optic will be placed at the entrance slit of the spectrometer. With a LiF prism the width of the slits opening for a spectral resolution of 0.1 micron will vary with wavelength from 0.52 mm at 1.0 microns to 1.79 mm at 5.0 microns.

The size of the image will be far smaller than these slit openings. However, it is planned to mount the spectrometer assembly on a MK-51 director. Since the balloon will be in constant motion, it does not appear possible to manually maintain the image in the entrance slit for any significant time. Some form of optical scanning is therefore indicated, whereby the image is oscillated across the entrance slit. The amplitude of the image motion would exceed the slit width dimensions to facilitate greater ease in tracking.

It was felt that manual tracking with an accuracy of ±0.25 degree could be accomplished by a trained operator. The total angular amplitude of optical scan need only be 0.50 degree (the vertex of which would lie at the principal plane of the collecting optic). The actual scanning will very likely be done by means of an oscillating secondary plane mirror.

It is planned to interrupt the spectrometer radiation beam by means of an internal chopper at a rate of 80 cps. It is further planned that the electrical passband of the amplifiers be made 5 cps. To produce a spectrum of 5 cps about the center frequency of 80 cps, it is necessary to produce at least 16 electrical signal pulses during the interval in which the image is situated in the entrance slit, i.e., not less than 1/5 second.

Since the optics within the spectrometer have an aperture rating of f/5, the rating of the external optic should not exceed this. A 12-inch-diameter collecting mirror should have a focal length of 60 inches. The total amplitude of image motion for a tracking accuracy of ±0.25 degree will be

$$\frac{(0.25)(2)(60)(25.4)}{57.3} \neq 13.3 \text{ mm.}$$

If the optical scan is linear, the required time for one complete scan with the minimum slit width of 0.52 mm (as required for 0.1-micron resolution at 1.0 micron with the LiF prism) will be

$$(1/5)(13.3/0.52) = 5.1 \text{ seconds.}$$

If one optical scan is desired during each 0.1-micron spectral interval, the time required to examine the spectral region from 1.0 through 5.5 microns is

$$(45)(5.1) = 230 \text{ seconds}$$
$$= 3.83 \text{ minutes} .$$

To determine what detector or detectors should be employed with the spectrometer to provide optimum measuring capability, the performance of various-type detectors were estimated in terms of the anticipated signal-to-noise ratio. These were computed and are for an anticipated path length of 30,000 feet and the lowest useful emitter radiation of 1200 watts/ster., i.e., a source at approximately 1070°K, then for a source at 1500° and 1900°K. The values of transmission were obtained from data computed by AVCO (Cincinnati, Ohio) describing the results of solar-radiation measurements and atmospheric transmission data for vertical and slant paths. These values are listed in Table 1 and describe the estimated atmospheric transmittance through a vertical path of 30,000 feet from sea level for an average clear day in which T = 70°F. and R. H. = 60%.

The irradiance at the collecting optic was determined for three emitter temperatures, 1070°, 1500°, and 1900°K. The first represents the minimum temperature which the emitter should exceed during a period of 15 minutes; the last temperature is probably the highest the emitter will attain at altitudes above sea level after it is ignited. The estimated values of irradiance at a vertical range of 30,000 feet from sea level for $\Delta\lambda = 0.1$ micron are described in Table 2 and are given for the spectral range of 1.0 through 5.3 microns.

The values of $\overline{NEH}(\lambda)$ for the various detectors considered were obtained as follows:

PbTe, (Syracuse University), Properties of Photoconductive Detectors, NBS Report 30-E-116, 3rd Report, 1 April 1953

InSb, (CML Z9), CML Spec and Performance Record

PbS, (Eastman Kodak)(I. R. I.), NOL Corona Report 256, March 1955

Infratron Detectors, Technical bulletins Nos. 1 and 2, Infrared Industries, Inc., published 1958-1959

The estimated $S/N^{(\lambda)}$ values for the various type detectors are tabulated in Table 3.

Table 1

Estimated Atmospheric Transmittance Through a 30,000-Ft Vertical Path for an Average Clear Day

Temperature: 70°F
Relative Humidity: 60%

Range: 30,000 ft
$\Delta\lambda$ = 0.1 micron

Wavelength, λ (microns)	Transmission, $\overline{T_A(\lambda)}$	Wavelength, λ (microns)	Transmission, $\overline{T_A(\lambda)}$
1.0	~0.8	3.2	0.10
1.1	ab*	3.3	0.25
1.2	~0.8	3.4	0.55
1.3	ab*	3.5	0.80
1.4	ab*	3.6	0.90
1.5	~0.8	3.7	0.95
1.6	~0.8	3.8	0.98
1.7	ac*	3.9	0.98
1.8	ac*	4.0	0.95
1.9	ac*	4.1	0.85
2.0	0.63	4.2	0
2.1	0.94	4.3	0
2.2	0.98	4.4	0.02
2.3	0.95	4.5	0.36
2.4	0.85	4.6	0.36
2.5	0.22	4.7	0.25
2.6	0	4.8	0.14
2.7	0	4.9	0.09
2.8	0	5.0	0.06
2.9	0	5.1	0.01
3.0	0	5.2	0
3.1	0.02	5.3	0

*See the following notes:

a: Good estimates of atmospheric transmittance along vertical paths were not available for these wavelengths. Since absorption will occur at these wavelengths due to the presence of water vapor the transmittance will be less than 0.8.

b: For these wavelengths the absorption is relatively weak and the transmittance may be over 0.4.

c: For these wavelengths the absorption is strong and the transmittance may approach zero.

Table 2

Irradiance at Collecting Mirror of Spectrometer Assembly for Various Emitter Temperatures

Range: 30,000 ft **$\Delta\lambda$ = 0.1 micron**

Wave-length, λ (μ)	Radiance, $\overline{H(\Delta\lambda)}$ (watts/cm^2)			Wave-length, λ (μ)	Radiance, $\overline{H(\Delta\lambda)}$ (watts/cm^2)		
	T = 1070°K	T = 1500°K	T = 1900°K		T = 1070°K	T = 1500°K	T = 1900°K
1.0	8.8×10^{-13}	4.0×10^{-11}	3.0×10^{-10}	3.2	3.2×10^{-12}	1.1×10^{-11}	2.2×10^{-11}
1.1	ab*			3.3	7.9	2.6	5.1
1.2	3.3×10^{-12}	8.0×10^{-11}	4.3×10^{-10}	3.4	1.7×10^{-11}	5.5	1.0×10^{-10}
1.3	ab*			3.5	2.4	7.5	1.4
1.4	ab*			3.6	2.6	7.9	1.5
1.5	9.9×10^{-12}	1.3×10^{-10}	4.9×10^{-10}	3.7	2.6	7.9	1.4
1.6	1.25×10^{-11}	1.4	4.9	3.8	2.6	7.6	1.4
1.7	ac*			3.9	2.5	7.2	1.3
1.8	ac*			4.0	2.4	6.6	1.2
1.9	ac*			4.1	2.0	5.6	9.8×10^{-11}
2.0	1.7×10^{-11}	1.2×10^{-10}	3.3×10^{-10}	4.2	0	0	0
2.1	2.75	1.7	4.6	4.3	0	0	0
2.2	3.0	5.8	4.5	4.4	4.3×10^{-13}	1.1×10^{-12}	1.9×10^{-12}
2.3	3.1	5.4	4.0	4.5	7.4×10^{-12}	1.9×10^{-11}	3.2×10^{-11}
2.4	2.8	1.4	3.4	4.6	7.1	1.8	3.0
2.5	7.5	3.6	8.2×10^{-11}	4.7	4.7	1.2	1.9
2.6	0	0	0	4.8	2.5	6.2×10^{-12}	1.0
2.7	0	0	0	4.9	1.6	3.7	6.1×10^{-12}
2.8	0	0	0	5.0	1.0	2.4	3.9
2.9	0	0	0	5.1	1.6×10^{-13}	3.7×10^{-13}	6.1×10^{-13}
3.0	0	0	0	5.2	0	0	0
3.1	6.62×10^{-13}	2.4×10^{-12}	4.8×10^{-12}	5.3	0	0	0

*See the following notes:

a: Good estimates of atmospheric transmittance along vertical paths were not available for these wavelengths. Since absorption will occur at these wavelengths due to the presence of water vapor the transmittance will be less than 0.8.

b: For these wavelengths the absorption is relatively weak and the transmittance may be over 0.4.

c: For these wavelengths the absorption is strong and the transmittance may approach zero.

Table 3

Estimated S/N(λ) with Various Detectors for Anticipated Emitter Temperatures

Range: 30,000 ft
Δλ = 0.1 micron

Collecting Mirror Area
(12-inch diameter): 585 cm^2

Wave-length, λ (μ)	S/N(λ) with PbTe Detector			S/N(λ) with InSb Detector			S/N(λ) with PbS Detector		
	T = 1070°K	T = 1500°K	T = 1900°K	T = 1070°K	T = 1500°K	T = 1900°K	T = 1070°K	T = 1500°K	T = 1900°K
1.0	0.656	30.3	226	2.05	94.5	718	28	1290	9,800
1.1	abd*								
1.2	2.71	66	353	10.88	265	1420	106	2580	13,800
1.3	abd*								
1.4	abd*								
1.5	9.48	123	470	54.6	705	2710	369	4760	18,300
1.6	12.64	140	495	77.2	850	3020	452	5000	17,700
1.7	acd*								
1.8	acd*								
1.9	acd*								
2.0	20.65	142	395	152	1048	2910	719	4960	13,750
2.1	35.6	d*	d*	269	d*	d*	1150	d*	d*
2.2	40.6	d*	d*	319	d*	d*	1270	d*	d*
2.3	43.4	d*	d*	338	d*	d*	1330	d*	d*
2.4	41.6	210	498	333	1675	3990	1250	6300	14,950
2.5	11.4	d*	d*	93.1	d*	d*	304	d*	d*
2.6	0			0			0		
2.7	0			0			0		
2.8	0			0			0		
2.9	0			0			0		
3.0	0			0			0		
3.1	1.26	4.5	9.0	5.13	18.3	36.8	1.2	4.3	8.6
3.2	6.35	21.8	43	52.4	180	356	3.05	10.4	20.7
3.3	15.7	d*	d*	131.6	d*	d*			
3.4	34.6	d*	d*	292	d*	d*			
3.5	50.0	157	295	430	1350	2540			
3.6	55.6	d*	d*	480	d*	d*			
3.7	58.3	d*	d*	510	d*	d*			
3.8	58.5	169	308	520	1500	2740			
3.9	57.6	d*	d*	525	d*	d*			
4.0	55.9	156	276	506	1414	2500			
4.1	47.8	d*	d*	450	d*	d*			
4.2	0			0					
4.3	0			0					
4.4	1.02	d*	d*	10	d*	d*			
4.5	18.45	46.8	80	187	474	810			
4.6	16.6	d*	d*	175	d*	d*			
4.7	10.7	d*	d*	119	d*	d*			
4.8	5.59	13.6	22.5	65	158	262			
4.9	3.27	d*	d*	40	d*	d*			
5.0	1.98	d*	d*	25.4	d*	d*			
5.1	0.29	0.68	1.1	4.0	9.4	15.3			
5.2	0			0					
5.3	0			0					

*See the following notes:

a: Good estimates of atmospheric transmittance along vertical paths were not available for these wavelengths. Since absorption will occur at these wavelengths due to the presence of water vapor the transmittance will be less than 0.8.

b: For these wavelengths the absorption is relatively weak and the transmittance may be over 0.4.

c: For these wavelengths the absorption is strong and the transmittance may approach zero.

d: Calculations were made for temperatures other than 1070°K only for selected wavelengths in the atmospheric windows.

It is clear from these studies that an adequate record should be possible even at the lowest proposed crucible operating temperatures. It appears as if one can expect considerably better range and records during the periods immediately after ignition when the radiant intensity is about two orders of magnitude higher than it is at the lower limit of 1070°K.

The next problem is that of developing a simple Thermit emitter temperature sensor and telemetering system. The entire program depends heavily upon a satisfactory solution of the problem of accurately measuring radiant energy emitted within certain wavelength intervals by each and every of the thermal sources at all times during the balloon flight. Presumably, this will require either a radiation-measuring device or an emitter-surface-temperature detector which would be carried aloft along with the thermal emitters. The detector would sample and measure either of the two variables at selected intervals of time and telemeter the information to the ground station. From this information the spectral intensity incident at the ground station without atmospheric attenuation may be computed.

Of the many possible devices for detecting either of the above variables, only three have been selected and studied as a practical and economically feasible system. These systems are: (1) an electronically amplified radiation pyrometer with associated filters passing radiation in the interval 0.7 to 0.9 micron, (2) a platinum-rhodium or rhodium resistance thermometer imbedded just below the surface of the emitter, a resistor switcher, amplifier and null detector, (3) a platinum vs. platinum-13% rhodium thermocouple imbedded just below the surface of each emitter, with an associated TC switching device, a D-C converter, a potentiometer, amplifier and a null detector. All three devices require sequential switching of each target to the input of the detector.

Of these three devices, the radiation pyrometer would perhaps be the most sensitive and have the advantage of measuring the total spectral emittance (0.8 micron) from each target but it would be difficult to keep in calibration. Furthermore, the optics appear to be cumbersome and excessively complicated. The resistance bridge and thermocouple potentiometer have the advantage of null detection and would be reasonably free of error resulting from variation of amplifier characteristics. The resistance thermometer bridge also could be A-C excited, avoiding the obvious disadvantage associated with high-gain D-C amplification or the alternative of radiation chopper or DC-to-AC electromechanical converters. Outweighing the advantage of the inherent simplicity of the resistance bridge is the error introduced by resistance-temperature hysteresis (which results when the resistor is subjected to wide temperature ranges extending to very high temperatures) which may be quite large.

In view of the above limitations, the thermocouple with associated input TC switch, DC-to-AC converter, continuously varying potentiometer and null detector appears to be the simplest and inherently the most stable detector giving an over-all measurement error of 1% or less.

Figure 1 is a block diagram of the proposed high-altitude thermocouple switching and Thermit emitter temperature detector. A_1 is the high-temperature thermojunction (one for each emitter), A_2 represents the cold junction and B is the standard reference voltage (about 10 mV). C is a six-position-rotary low-contact-noise make-before-break single-pole switch which is sequentially switched from E_s to TC_1, TC_2 on to TC_5 at five-second intervals by pulses from the cam-activated microswitch D_2. The potential appearing at the center tap of the input transformer T_1, is balanced by R_s, (D_1), a continuously rotating single-turn helipot of 250 ohms maximum. At balance, the voltage at center tap is zero. The voltage is positive and maximum when the helipot is turned through zero angle and negative and maximum at 360° angle. The helipot and associated cams D_2 and D_3 (on the same drive shaft) are driven by the low-power 60-cycle-synchronous motor M, supplied by the 60-cycle oscillator and power amplifier F. The oscillator also supplies in-phase 60-cycle signals to T_4, chopper E, gate input G_2 and read-out gate D_3. D_3 is a cam-operated microswitch which is turned on when the helipot is at 295° and gates the shift-right read-out pulse to the binary storage register. In operation, gate G_2 will always be off when gate D_3 is on and vice versa. A subcycle of operation then behaves as follows. Assume an instantaneous switch to TC_1. The position of the helipot will be at zero degree (i.e., R_s is zero) and since the polarity of the thermocouple is such that the center tap of T_1 will be positive, the A-C-amplified signal at T_3 of the phase-sensitive detector will be in-phase (or nearly in-phase, this is not critical) with the oscillator signal at T_4. The D-C-signal polarity at gate G_1 will be negative turning on gate G_2. A number of signal cycles from the oscillator will pass through gate G_2 to the binary counter. At some point on R_s, the potential at T_1 is zero and then becomes increasingly negative timewise. The out-of-phase signals now appearing at T_3 and T_4 produce an increasingly positive bias at gate G_1 turning gate G_2 off and the signals to scalar will stop. This will always occur before helipot has turned through 290°. When the helipot has turned to 290°, gate D_3 turns on and oscillator signals pass to read-out binary storage register. D_3 shuts off at or near 350°. At 355°, D_2 activates the microswitch and shifts the TC switch to TC_2. However, gate G_2 remains off until R_3 has rotated to zero degree or $R_s = 0$, at which time the output signal to G_1 goes from positive to negative. The time required for one subcycle or a 360° rotation of R_s is five seconds.

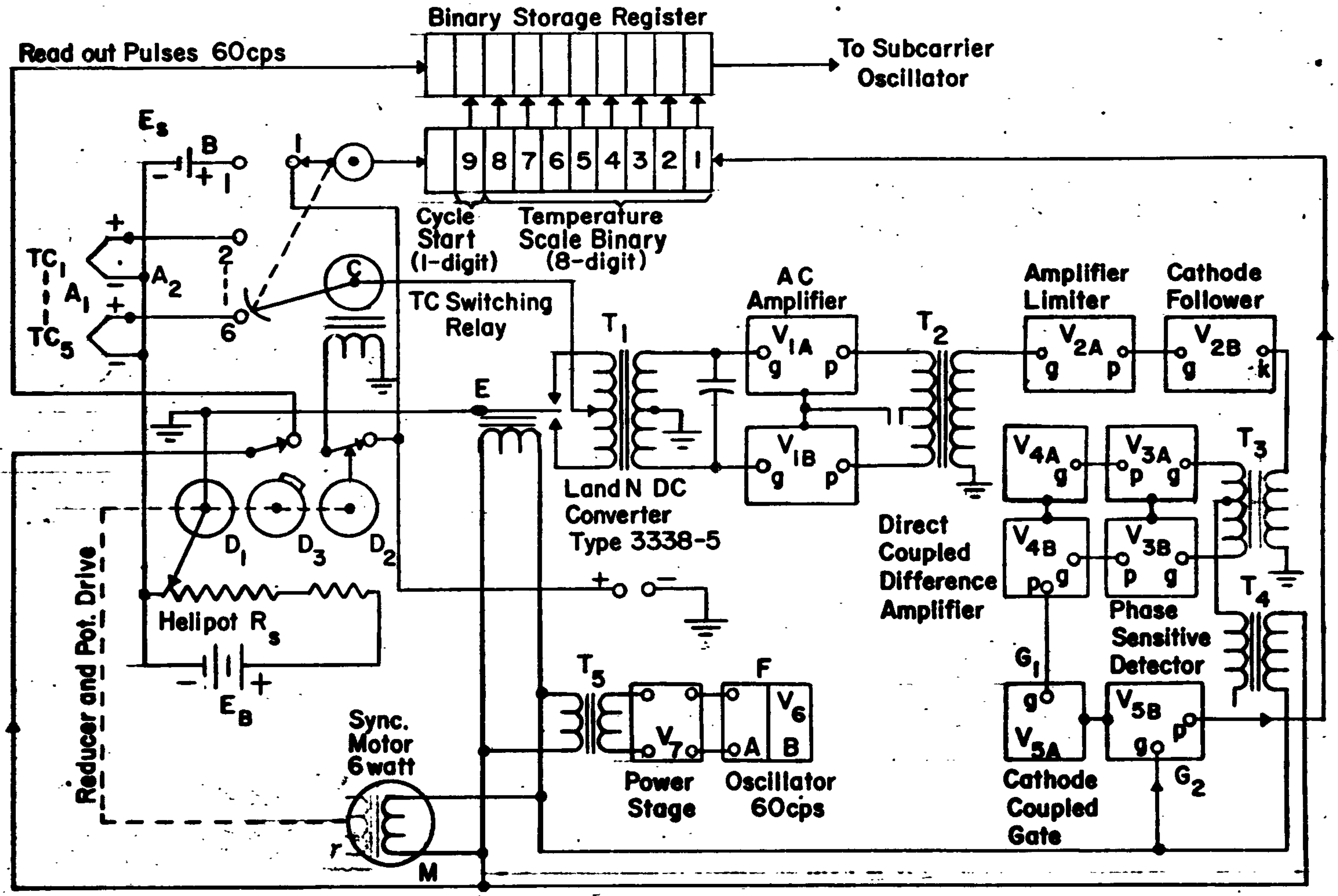

Figure 1. Proposed thermocouple switching Thermit emitter temperature detector.

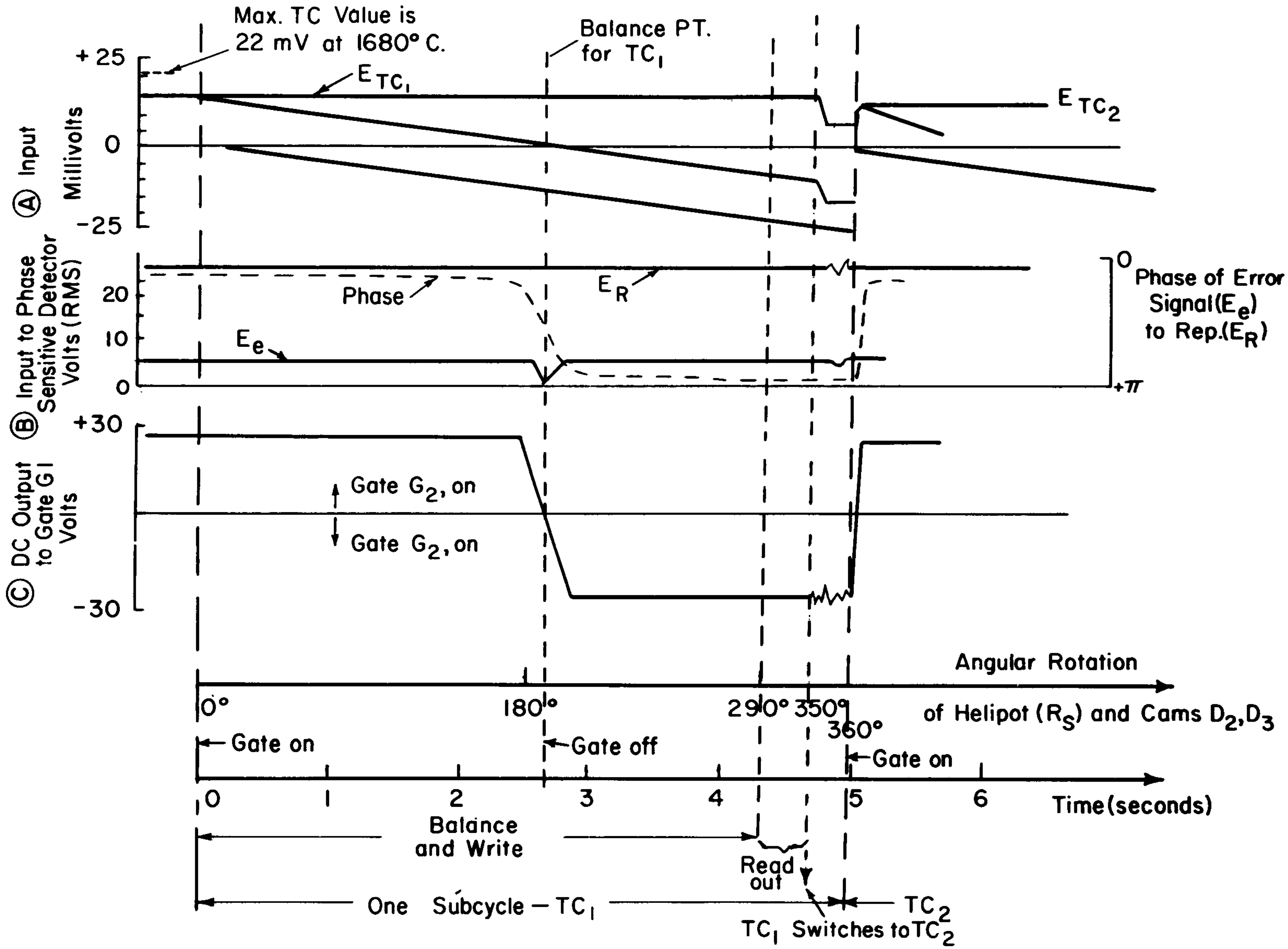

Figure 2. Voltage and phase relations at various stages of amplification.

Thus, each Thermit emitter and reference voltage E_s, is monitored every 30 seconds. The binary information stored in the register is shifted out by oscillator signals through gate D_3 and used to modulate the subcarrier oscillator which in turn is transmitted to the ground station.

Figure 2 is a graph showing potential and phase relations at various times during a cycle of operation.

Respectfully submitted,
CHICAGO MIDWAY LABORATORIES

(8) Lucien M. Biberman
Director, Systems Division

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Appendix A

SUMMARY OF MEETING BETWEEN PERSONNEL OF CHICAGO MIDWAY LABORATORIES AND LOWRY AIR FORCE BASE

9 June 1959

A meeting was held 9 June 1959 at Chicago Midway Laboratories (CML) in which the 1110th Balloon Activities Group (1110th BAG) from Lowry Air Force Base was represented by Lt. Col. A. J. Daly, Commander, Maj. K. D. Swisher, Capt. R. Armstrong, and Capt. O. H. Archer. The CML staff members in attendance were Lucien M. Biberman, Director of the Systems Division, and the following project personnel: G. R. Ban, M. Rusnak, W. E. Six, H. P. Thomas and Serena Torres.

Mr. Biberman outlined the program objectives as follows:

1. Determine the atmospheric attenuation slant paths extending from essentially sea level to and above the tropopause, if feasible.

2. Make available such attenuation data allowing correction to absolute values of other measurements of apparent radiant intensity of targets of military interest.

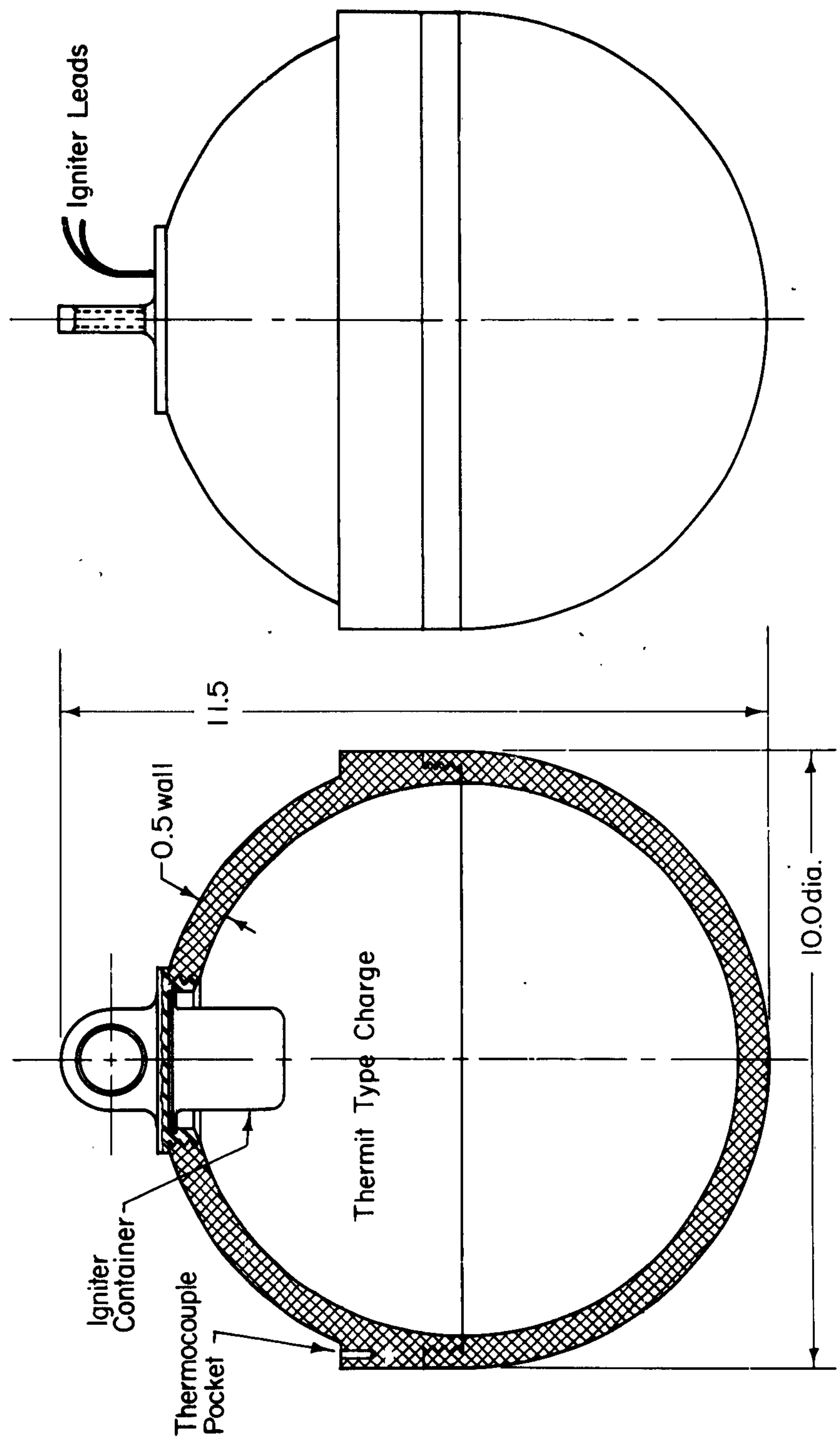
3. Permit analysis of attenuation data, and correlate with meteorological data.

4. Gain a better understanding of the basic roles of absorption and scattering in such paths.

The data needed to accomplish these goals will be obtained from balloon flights. The radiant power at the ground resulting from standard sources sent aloft will be measured with a standard receiver (spectrometer) which yields apparent spectral radiant intensity (J_λ) as a function of wavelength for wavelengths between 1 to 6 microns and 8 to 14 microns. The spectrometer requires about 4 minutes to cover this range, during which time the source on the balloon will have traveled away from the receiver, thereby decreasing the indicent radiant power. Therefore, the indicated radiant intensity is a function of wavelength source temperature and distance.

The sources will be hermetically sealed graphite crucibles containing Thermit, a mixture of aluminum dust and iron oxide. One form of crucible being considered is shown in Fig. A-1. The life of a Thermit emitter is about 20 minutes, so if five emitters are used successively, the total time available for making measurements will be about 100 minutes. The rate of balloon ascent should not exceed 300 or 400 feet per minute to minimize the effect of changing distance upon measured radiance.

The temperature of the Thermit pot varies over its 20-minute burning time. Its maximum temperature of about 3000°F is reached after approximately 40 seconds and drops rapidly for the next several minutes. To obtain the required data, it is essential that the radiance be known at several (4 or 5) instants so that a source-radiance time curve can be plotted.


Igniter Leads
11.5
0.5 wall
10.0 dia.
Thermit Type Charge
Igniter Container
Thermocouple Pocket

An estimated curve is shown as Fig. A-2. The method by which this is to be accomplished is one of the important questions which has been previously discussed.

On the ground, radar will provide range, azimuth, and elevation data. An aluminum-foil corner reflector will be attached to the balloon's lead line to facilitate radar tracking.

The Air Force personnel outlined the method of launching balloons, pointing out the various alternatives which call for decisions on the part of CML. Balloons are launched from the ground. The load is carried by a vehicle (e.g., a jeep) which travels under the balloon until the load line is vertical, at which time the load is freed to ascend. The bar or wheel carrying the emitters will be suspended from the balloon at the end of the load line. The instrumentation will hang in a padded bag cushioned with styrofoam well above the Thermit emitters. Above that, the telemetering radar reflector, and an open, limp parachute will be attached to, or inserted in, the load line. The balloons are designed to float at an altitude of 70,000 ft with 250 pounds of payload. The usual rate of ascent is 700 ft/min, but this rate can probably be slowed to between 300 and 500 ft/min below 28,000 ft. Hence, in the 100 minutes during which measurements can be made (assuming that five pots are used) the balloon will have risen to between 30,000 and 50,000 ft. The horizontal drift at 40,000 ft over Florida may be as large as 15 miles, thus yielding a slant range of about 17 miles. This horizontal displacement is greatest during November and December. At Antigua, balloons rise spirally within about a 65° cone. Lowry Air Force Base will furnish balloons, lights (two flashing-red automobile-direction-indicator lamps), parachutes, load lines, and, if they are used, bars and fittings.

The airborne clock is a most important piece of equipment. It may be either spring-wound or motorized, but it must be accurate. Its functions are to accomplish the ignition of each emitter, the cutdown of the package, and the descent of the balloon. Each function may be performed by a separate clock, or a single control unit may combine all the functions. Lowry may be able to furnish GMI clocks with five cams to perform five functions. Otherwise, CML must furnish the baro switches for time and altitude functions to cut down the balloon, and a 12-hour termination clock. These can be purchased together with a mercury impact switch in a package called the "Standard GMI Grab Bag Auxiliary Safety Timer" from Raven Industries for about $150 each. The 1110th BAG will send the GMI drawings to CML. CML will obtain a quotation from Raven with a copy to 1110th. A 17-function control unit known to 1110th BAG may be able to perform all the necessary functions. Capt. Archer will investigate the possibility of obtaining and using the controls. The performance of an adjustable aneroid barometer has not yet been made an Air Force specification item, but may be soon, in which case CML must also furnish this equipment.

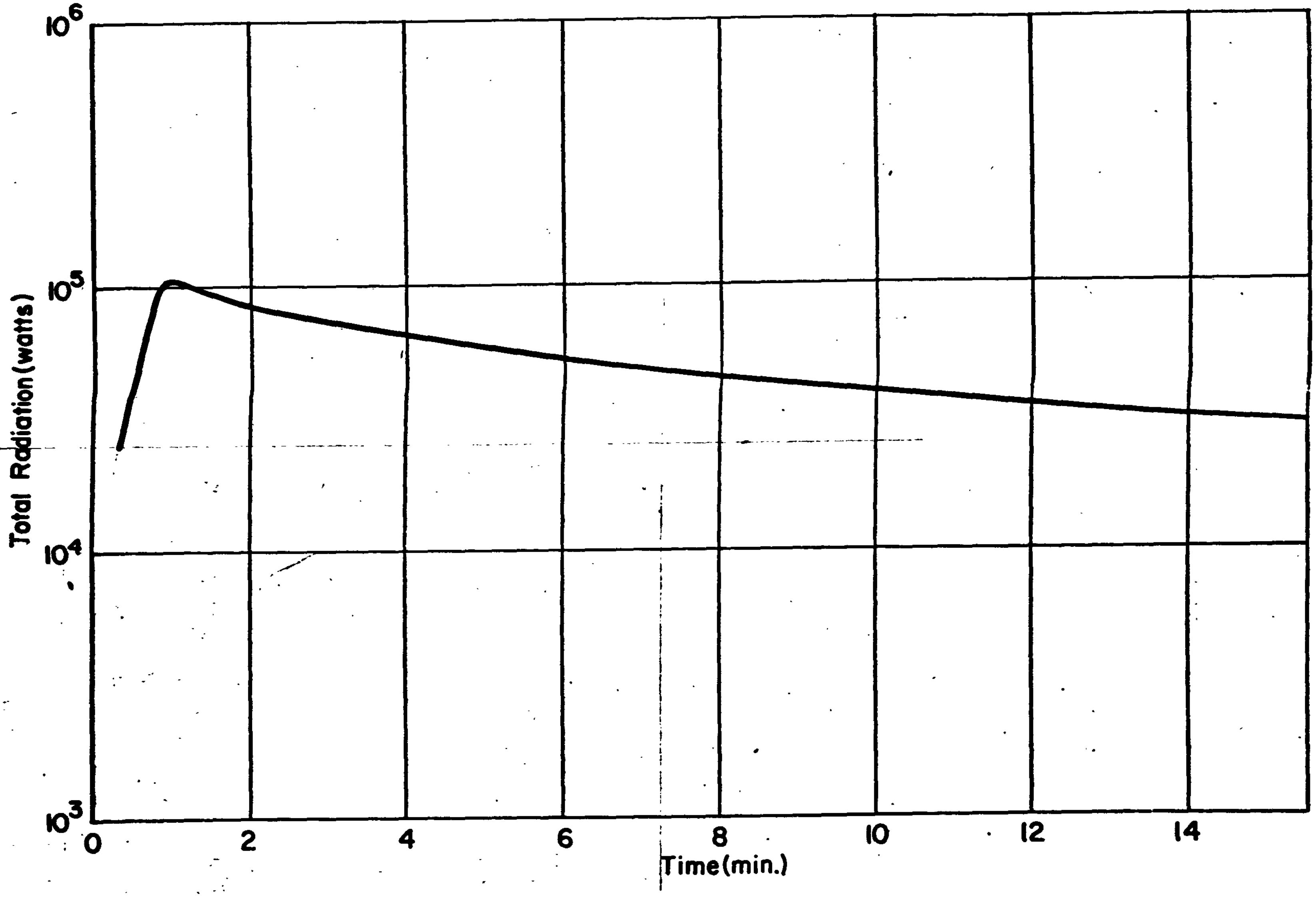


Figure A-2. Total radiation versus time.

Mr. Biberman prefers to make the first measurements from Cape Canaveral rather than from Patrick Air Force Base in order that auxiliary measurements may be made from missiles launched there. As the maximum distance at which it will be possible to make measurements is about 20 miles and the lateral displacement of balloons launched in Florida is considerable, Col. Daly suggested the possibility of launching from a site remote from the receiving station so that the balloon would be approximately over the station when the emitters are ignited. Mr. Biberman said that in that case, he would prefer that each balloon carry only one or two pots. He then raised the question of the cost of balloon vs. the instrumentation it will carry and learned that a balloon costs between $500 and $600, hence about 1/3 the cost of the instrumentation. A meeting will be held at Patrick Air Force Base to settle the questions of where the launch site will be and what ground instrumentation will be available.